6th SETAC-Europe Meeting: LCA – Selected Papers

Iterative Screening LCA in an Eco-Design Tool

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Abstract

A screening and simplified LCA method is essential necessary to include environmental aspects in the stage of Research and Development (R&D) of products and processes. An interactive, iterative and integrative eco-design tool using the top-down approach in the identification of advanced materials is being developed in a joint project performed by six research institutes. The principles and methods as well as some examples for the validation of the screening LCA as well as its application in eco-design in case studies are presented in this article.

Keywords: Life Cycle Assessment; screening LCA; simplifying LCA; streamlining LCA; eco-design; eco-materials; pollution prevention; automotive industry

1 Introduction

Nowadays, the designers of (new) products have to consider more than technological feasibility of the materials used in manufacturing for the products. The reason is that sustainability (i. e. the strategic long term competitiveness of products) can only be ensured if more selection criteria than the "classical" ones are taken into account during R&D. In R&D more than 60 % of the economic – and probably the environmental – costs are fixed for the future life cycle of a product. An eco-design tool that looks at all possible materials and composite materials (top-down approach looking at all polymers, metals, ceramics etc. as well as at all possible combinations) is therefore being developed by six German research institutes. It integrates five selection criteria *(→ Fig. 1)*:

- Technological feasibility of the products that includes the characteristics of the materials (using databases, estimation rules for characteristics of new composite materials etc.), the options for production and fabrication,
- recyclability (technological efforts for recycling, quality of recycling products, recycling yield, kind of recycling loop, i.e. energy, chemical/feedstock, materials recycling or reuse),
- working Conditions (handling of hazardous substances, working climate, physical strains, radiation, noise and mechanical vibrations during the working processes of the life cycle),
- competitiveness (life cycle costs and benefits from cradle-to-grave of the products including the costs of R&D),
- environment (environmental burdens from cradle-to-grave using the (Iterative Screening) LCA methodology)

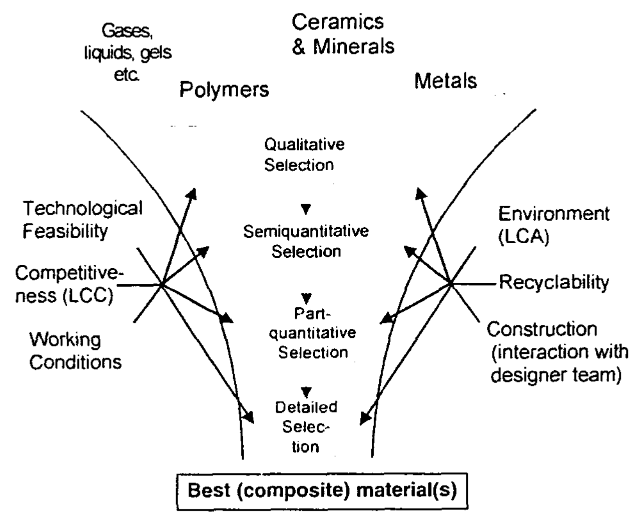

Fig. 1: Top-down eco-design tool for the selection of materials

Working conditions, costs and environmental inputs and outputs are assessed using the life cycle thinking approach. The aspects of engineering construction is included by an interactive feedback with the designer team.

The main point in this eco-design tool is that we are looking at all possible materials and materials combinations – often this is a countless number ! The reason for using this top-down approach is being that we want to identify the "best" (composite) materials out of the existing and up-to-now non-existing materials solutions for this application in question (and in general). So we have developed an iterative approach within which the level of detail concerning system boundaries, data quality, relevant parameters, etc. is increased step by step (regarding all selection criteria). Using this procedure, one can handle a great number of compared options in a relatively short period of time. This iterative approach (qualitative, semi-quantitative, part-quantitative and, finally, full quantitative examination of materials) is performed accompanying to the R&D of products or processes. After each iteration step there is a feedback with the designer team in order to check whether modifications of the engineering construction would be promising and allow the use of materials which would otherwise be excluded.

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Compared to other eco-design and DfE (Design for Environment) methods, this eco-design tool (called euroMat for "entwicklungsbegleitendes Instrument für umwelt- und recyclingorientierte Materiallösungen" or tool for the identification of environmentally friendly and recycable materials accompanying the development) demonstrates the following specific characteristics:

- it looks at all possible material combinations (including new material combinations that have not existed in the past), i. e. a strategic advice is provided the materials that should be developed further for this application,
- it integrates a comprehensive set of the most important selection criteria (see above),
- it accompanies the process of product engineering design by using an iterative approach, i. e. shortening the time of development and reducing costs in R&D by giving advise very early in order to decide if a certain direction of a product development seems to be positive or negative.

Table 1: ABC-assessment for a rough identification of ecological hot spots [2]

Eco-Importance	Criteria
A (high)	1. carcinogen/mutagenic substances, 2. persistent and toxic or very toxic substances* or 3. other qualitatively distinguishable hot spots+
B (middle)	1. substances which are acidic, allergenic or less toxic or 2. substances which are not A or C
C (small/no)	1. inert, non-toxic emissions or 2. no known or small# qualitative problems

* e.g. listed in German list of water endangering substances (WGK 2 and 3) or of hazardous substances (categories 1 to 3 and T+)
+ e.g. ozone depletion substances, relatively high global warming potential, harvesting of unsustainable rain forests
# e.g. small global warming potential, WGK 0, not distinguishable to an average background concentration
note: the "normal" or "background" level has to be exeeded to get an A, B or C

2 Iterative Screening LCA (IS-LCA)

The iterative approach mentioned is also performed for LCA (→ *Fig. 2)* [1, 2]. The iterative approach is necessary to adapt the LCA procedure to the classical design process which is an iterative one (from the starting idea to some concept stages and ultimately to a final constructional plan). In most cases qualitative information is available in the beginning (construction principles, requirements concerning strength and other characteristics). Step by step, the level of available information increases. Consequently, the same approach has to be used in eco-design.

Therefore, the first iteration step of an IS-LCA has to be a qualitative one: Criteria for an ABC assessment in eco-design (A = attention – environmental problems, C = no significant problems) have been developed concerning the (eco-) toxicity of the emissions of the main process sequence *(→ Table 1)*. Screening indicators like material consumption [8], energy consumption [9], or the occurrence of key substances (e. g. heavy metals) are not applicable at this design stage due to the lack of quantitative information

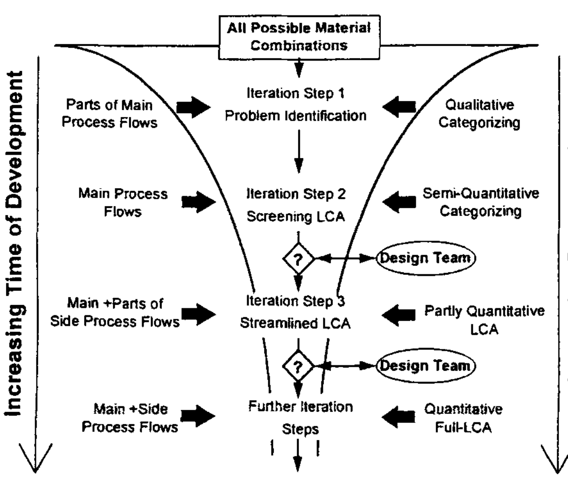


Fig. 2: Iterative screening life cycle assessment in eco-design

(e. g. concerning the exact weight of the product). The aim of the first iteration step is to identify the main problems that to focus on in further iteration steps.

The second iteration step is semi-quantitative. The consumption of energy is the most suitable quantitative screening indicator because of its big influence on Global Warming Potential, Resource Depletion, Acidification Potential, etc. This screening indicator is supplemented by an ABC assessment as described above and an XYZ assessment regarding the amount of a substance (X = great, Z = small). A rule of thumb for the combination of ABC and XYZ assessments is as follows: the more serious the environmental problems associated with an emission, the smaller the amount of the emission may be to get an "X"-rating. ABC/XYZ ratings are made operational by using weighting factors for the aggregation. Besides energy and the ABC/XYZ assessment, possible screening indicators could be materials consumption, waste generation and, certain key emissions of the systems, as e.g. ozone depleting substances. These screening indicator are not very common but may be applied additionally. The best screening indicator can be identified by an experts' panel, by screening literature and LCAs in this or/similar fields, or by using check-lists (e. g. [7]). It should express a very strong connection with the most important environmental inputs and outputs of the compared systems. The importance of the burdens is identified through valuation/interpretation and the screening indicator.

The third iteration step is part-quantitative. All data concerning Global Warming Potential, Acidification Potential, Resource Depletion, Nitrification Potential, etc. are taken into account. Further iteration steps look at all inputs and outputs with an increasing level of representativity. The system boundaries are enlarged stepwise. This increase of detail is stopped as soon as the results are becoming stable and the level of confidence is sufficient for the decision maker.

3 Validation

As mentioned above, one often uses energy consumption as a screening indicator. This screening indicator is diversified into fossil, nuclear and other energy sources in order to take regard of the fact that some materials cause the use of special kinds of energy. When using a mix of all energy types, energy is a good screening indicator, which reflects a lot of environmental problems. For example, over 60 % of the global warming problem is caused by energy consumption. Similar numbers for other key emissions that cause acidification, L.A.-smog, etc. *(→ Fig. 3)*. However, this only reveals one side of the medal. Other aspects like (eco-) toxicity are not represented by energy consumption. Radioactivity which can cause cancer, for example is only originates to 25 % via energy activities (other examples are heavy metals, organohalogens, etc.). This is one reason why an ABC assessment for (eco-) toxicity completes the screening indicator "energy consumption" in IS-LCA.

In addition, the method was tested in reference to well performed full LCAs like the one for different beverage systems, which was published by the German Environmental Agency UBA [3], to ensure that the iteration steps converge to the "true" results and that correct screening results are achievable in general. This UBA LCA provides no clear results but, according to a sensitivity analysis, the best beverage system is the plastic bag and the worst option the gable top made out of composite materials. As seen in **Figure 4**, an equivalent interpretation is the outcome of the second iteration step of the IS-LCA method. The result is stable in the third iteration step. This is only one example that verifies the method of Iterative Screening-LCA.

4 Application in Eco-design

At present **ten examples** of different industrial products are under examination to prove the usefulness and practicability of the Eco-design tool euroMat. One example is the bottom of a car body. The automobile in question is a prototype of an Eastern German car manufacturer (Sachsenring). It is a spaceframe automobile where the main function of the bottom of the car body is to keep the weather

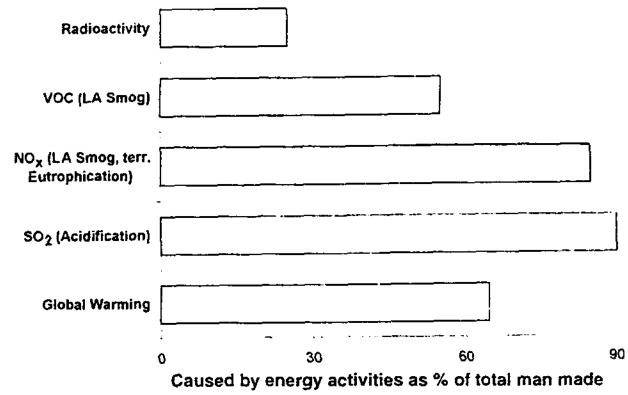


Fig. 3: Selected impacts of energy activities in comparison to the total man-made impacts [4, 5]

influences out and to carry the weight of the passengers. The prototype will be produced using aluminium for the investigated part. The question is whether other materials have better characteristics concerning environment, economics, recycling, technology, and working conditions.

The second iteration step of just five of the examined alternatives to aluminium is presented in **Figure 5**: The assessments of two sandwich materials, two fiber reinforced plastics, and a steel using a lightweight construction (lockbead construction) are shown. The second iteration step of IS-LCA includes energy consumption and the ABC/XYZ assessment (see above).

The energy consumption of these materials in relation to aluminium is calculated cradle-to-grave (including recycling). The functional unit is a bottom of a car body, which is to be used for ten years. The four composite materials have a lower energy consumption than aluminium. Lightweight steel is in the same order of magnitude. According to experiences in applying euroMat, differences up 20 % should not lead to differing interpretations due to the level of confidence at this stage. This energy related screening is completed by an ABC/XYZ assessment for the relative environmental problems (see *Table 1*). Here, the duroplastic sandwich composite is less favorable than aluminium due to hardening agents, substances like epichlorinehydrine, etc.

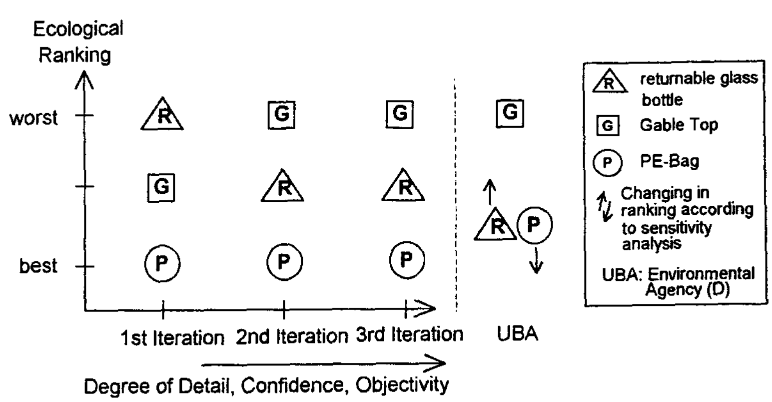


Fig. 4: Ranking of the environmental friendliness for different milk packaging systems

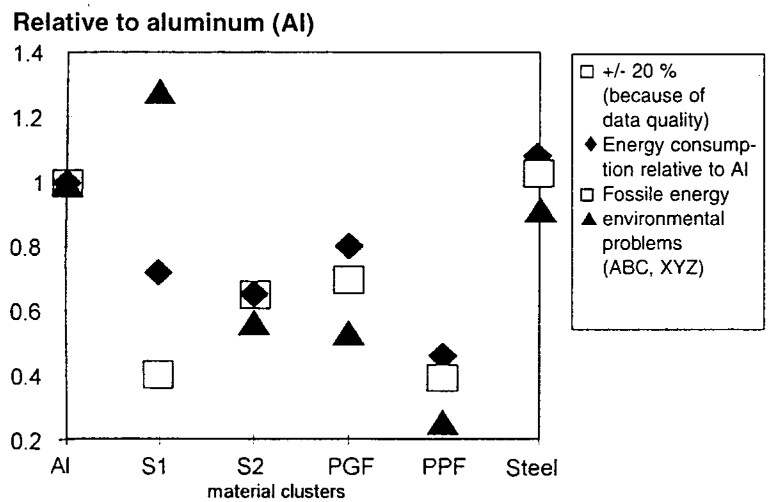
Following the ranking of the different materials solutions, this screening result is one among others for the selection criteria technological feasibility, recyclability, competitiveness, working conditions (→ *Fig. 6*). In this figure, all interpretation results (ranking of the materials for every selection criterion) are compared. The best assessment leads to a corresponding high score in the diagram.

In addition, the special level of confidence for certain materials (e.g. in cases of not yet existing composites) have to be outlined in order to give recommendations to the designer team. During and especially after each iteration step, one gets a feedback and new information (e.g. about an improved construction of the product) from the designer team as a basis for further iteration steps until the designer team states that the level of confidence is high enough to make a decision (i. e. material selection).

5 Conclusions

Screening and simplifying approaches are essential if one wants to include environmental aspects in a very early stage of product development. Only if the data needed for an LCA is adapted to the available data within the engineering design process it is possible to look at environmental aspects in the state of product development. The Iterative Screening LCA is a tool to deal with this issue efficiently.

A very effective stage for pollution prevention (P2) is the design process. In consequence, screening is an important LCA modification for ensuring the practicability and efficiency of P2, especially in the sector of R&D. Further research can be identified on this field, i. e. concerning screening indicators, reliability, etc.



S1: sandwich 1 (Duroplatz + distance structure); **S2:** sandwich 2 (Polyolefine + plastic fiber + Al); **PGF**: Cluster Polyolefine + glass fiber; **PPF**: Cluster Polyolefine + plastic fiber

Fig. 5: Energy consumption and environmental problems of material alternatives relative to aluminum

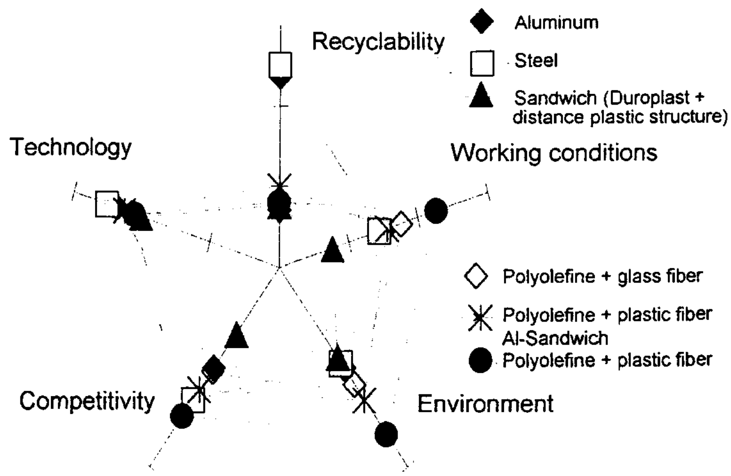


Fig. 6: Results of selection criteria for different materials in the bottom of a car body

Acknowledgement

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News & Views

Spanish Association for the Promotion of LCA Development (APRODACV)

Workshop Plan, Spring 1997

APRODACV, the Spanish Association for the Promotion of LCA Development, is organizing its first LCA meeting of experts. The workshop will be attended by approximately 40 experts from the public and private sector. Its aim is to exchange ideas, information and experiences, and collect alternative actions and proposals in the field of LCA. Another goal of this workshop is to enhance the contact between LCA experts and to share the knowledge on LCA in Spain. The application and implementation of LCA in Spain is still in an early state of development.

As a result of the workshop, a basic document will be written which would point at the main tasks and issues needed to carry out a Strategic Plan for the implementation of LCA as an environmental management tool in Spain before the year 2000.

The development of the workshop will be carried out according to the methodology developed by DGXIII (European Commission). This methodology aims at reaching an agreement in the main fields discussed in the workshop within a maximum period of two days.

The workshop will primarily be structured in four parts or sessions. Two of them are performed by working groups and the other two are plenary sessions:

In the **first session**, the experts will join different groups according to the following classification: Administration (public authorities); Consultancies and Engineering; Industry and Services; Research and Education, and NGOs (non-government organizations). In each group the most interesting ideas to implement LCA should be discussed.

As for the **second session**, all participants will come together to elect five proposals (elaborated by the different working groups) which should be the best to implement LCA in new products and processes in Spain before the year 2000.

In the **third session**, all participants will be distributed again in different groups: Packaging; Standardization and Eco-labelling; Waste Management; Product Design; Environmental Management, and Research/Education and Information. Each group will present a list of actions in its field and the Organization will vote for the three best actions proposed in each working group.

Finally, in the **fourth session** all members will come again and will vote on the three best options for all working groups. As a result, a final document should be written. The final documents should incorporate the discussions and the conclusions reached in this experts' workshop. This document will be published and sent to all interested parties: Administration, Business associations, University, NGOs,.... and, as said above, it should be The Strategic Plan to implement LCA in Spain.

Development of an Environmental Database for the Application of LCA in Catalonia

The objective of this project is to develop a tool for the performance of LCA in our country (Catalonia). The aim is to collect basic data considering the special geographical and technological features of Catalonia in such a way that it can be used as a basic source of information for the application of LCA to products and processes. It is also expected that the Administration will make use of this data to establish environmental policies with objective criteria.The project consists of elaborating a database of resources and basic operations to use and perform LCAs. The work is structured into three points:

1. Identification and classification of the basic data of materials, energy sources, transport and pollutants, and collection of background and specific data
2. Collection of exological indexes and adaptation of the impact assessment methods
3. Development of a software package to handle the database

The work will be performed by **four research** groups of the following Universities:

- Universitat Autònoma de Barcelona (including the collaboration of Randa Group S.A.)
- Universitat Rovira i Virgili
- Universitat de Girona

The project has been assigned an initial financial support by the Catalonian Government.

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